Engineering Physical Intelligence from Soft Machines to Mechanical Metamaterials

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Abstract: While neuron-based computational intelligence resides in the brain, physical intelligence emerges from the body, where structural mechanics and smart materials encode sensing, actuation, and decision-making directly into the system itself. By shifting part of the computational burden from the controller to the material body, we can create machines and materials that are inherently adaptive, efficient, and autonomous. In this talk, I will present a research framework that integrates computational modeling with soft active materials to bridge the gap between fundamental material behavior and robotic function, a central challenge at the intersection of materials science, mechanics, and intelligence. My goal is to harness snap-through instabilities and programmable morphologies to enable new capabilities in robotics, biomedical devices, and sustainable materials. I will illustrate this framework through three examples across scales. First, I will describe a butterfly stroke-like soft swimmer that exploits snap-through instability for rapid and energy-efficient locomotion. Second, I will discuss geometrically templated graphene oxide/polymer architected materials that combine ultralow density with high strength, showing how structural design can transform fragile soap films into robust mechanical metamaterials. Third, I will present a magnetic kirigami dome metasheet that integrates large deformability, structural stiffness, and magnetic programmability for adaptive shape morphing and multimodal manipulation. Together, these studies establish a strategy for developing next-generation soft materials and machines through their fabrics.

Bio: Yinding Chi is a postdoctoral researcher in Materials Science and Engineering at the University of Pennsylvania. Yinding earned his B.S. from Huazhong University of Science and Technology in 2014, followed by an M.S. from the University of Colorado Boulder in 2017. He received his Ph.D. in Mechanical and Aerospace Engineering from North Carolina State University in 2022. Yinding is a recipient of the 2022 PNAS Cozzarelli Prize from the National Academy of Sciences and the 2023 SES Future Faculty Award from the Society of Engineering.